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DEHYDRATED EXPLOSION PUFFED BLUEBERRIES

ABSTRACT

A new method for preparing dehydrated explosion puffed blueberries is described. Introduction of superheated steam into the explosive puffing gun has greatly reduced length of previously reported operating cycles, has made possible increased gun capacity, and has resulted in significant product improvement.

Results of storage tests on partially dried, unpuffed berries show that the operating season for explosive puffing can be extended, thus reducing costs. Storage data are given on dehydrated, explosion puffed berries at several temperature levels for air pack and inert-gas pack. Sufficient detail has been provided to enable a manufacturer to produce a high quality product.

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INTRODUCTION

Quick-cooking dehydrated fruits and vegetables prepared by the explosive puffing process have evoked great interest from food processors and the consuming public. The process, first developed at this Laboratory, has been extensively publicized (6, 9-14).[1] Continuing technological advances and process improvements have rapidly outdated the fruit processing paper published 2 years ago (4). A newer and greatly improved method of preparing dehydrated explosion puffed blueberries is described in this publication.

The most significant innovation in explosive puffing is the continuous direct injection and through-flow of superheated steam in the gun during an operating cycle. By this means, pressures above atmospheric are quickly obtained, operating cycles are significantly shortened, and larger charges can be used. Flow of superheated steam through the charge rapidly heats water contained in the partially dried berries to a temperature above the atmospheric boiling point. Resultant products are greatly improved over those made by the obsolete method of using external heat alone. Superheated steam does not increase the moisture content of the discharged product to an objectionable degree as would saturated steam. Use of this new method has been described (12).

PROCESS DESCRIPTION

Procedures used in preparing most dehydrated explosion puffed commodities include the following: (1) raw material preparation, (2) preliminary drying to a suitable moisture content for explosion puffing, (3) explosion puffing, and (4) final drying of the puffed material to a moisture content conducive to good storage stability.

Raw Material Preparation

Blueberries, as contrasted to most commodities, require little preparation before explosion puffing other than removal of trash, occasional size grading, washing, and preliminary drying. Sulfiting, or other treatment to inhibit enzymatic action, was not necessary. Cultivated berries obtained fresh from New Jersey and Michigan were used in pilot plant studies. Size grading of these berries was sometimes necessary to ensure uniform initial drying if more than 10 percent by weight of the berries were not within 5/16 ±1/8 inch in diameter. The over and under screen fractions were partially dehydrated

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[1] Underscored numbers in parentheses refer to Literature Cited, p. 14.

separately to the same moisture content and later combined prior to puffing. In commercial practice berries would probably not be separated provided that sufficient time were allowed after drying for adequate moisture equilibration. Puncturing or scarifying the berry skin caused bleeding during drying and resulted in agglomerates that could not be puffed. Intact berries, however, could be successfully dried.

Preliminary Drying

Preliminary drying in the pilot plant studies was done in a cabinet-tray dryer in which hot air circulated through the bed of material. (In commercial practice, a conveyor-type dryer would probably be used.) Studies were made to determine optimum drying conditions based on final berry appearance, tray loading, air temperature, and drying time. Air temperatures of individual runs were held constant throughout. A range of 160° to 200° F. was studied with the wet bulb depression remaining constant. Individual tray loadings were varied from 7.8 lb. per sq. ft. to 14.5 lb. per sq. ft., which corresponded to bed depths of 2.0 to 4.3 inches. Initial airflow direction was either upflow or downflow and velocities were held between 150 and 250 f.p.m. Airflow direction was reversed halfway between the initial and explosion puffing moisture contents, and drying was continued until the latter moisture was achieved.

Drying studies, conducted during one season on Michigan and New Jersey berries, showed no difference in drying rates, appearance, or behavior. (The dehydrated explosion puffed products were in all respects the same.) A difference, however, was apparent between two successive seasons in New Jersey berries, possibly due to climatological changes; i.e., less rainfall at a critical period during the 1964 season than in 1965. This difference was most apparent in the heat sensitivity of the berries during drying. A hot air temperature of 200° F. was used successfully in 1964, but the drying temperature in 1965 was reduced to a maximum of 180° to prevent excessive bleeding of the berries. In 1964, a tray loading of 12 lb. per sq. ft. (4-inch bed depth) provided uniformity of drying. In 1965, the tray loading was reduced to 9.5 lb. per sq. ft. (3-inch bed depth) to achieve a partially dried product of equally suitable characteristics for puffing. (A drying temperature of 160°, even with low tray loadings, did not provide a sufficiently high drying rate to be practical commercially.) The direction of initial airflow was critical for the 1965 "wet" season, but immaterial for the previous season. Upflow air at 180° in 1965 caused excessive berry bleeding, probably due to contact with the hot metal surface of the drying tray. Downflow direction initially at the same temperature did not result in bleeding. Airflow direction was reversed after 50 percent of the moisture was removed.

Based on the above observations and accumulated data, it can reasonably be expected that despite seasonal variations the following drying conditions will provide satisfactory partially dried berries for explosion puffing: Through-flow air at 180° F. dry bulb, 100° wet bulb, initially in a downflow direction at 250 f.p.m. Tray, or belt, loading of 9.5 lb. per sq. ft. (3-inch bed depth). Reverse airflow direction at about 50 percent moisture removal, and continue drying at the same conditions to an end moisture of about 16 percent. The overall drying rate for these conditions was 1.9 lb. water removed per sq. ft. per hr. Drying time was 4 hours to reduce the moisture content from 84 percent to 16 percent. Product rate at 16 percent moisture would be 0.45 lb. per hr.

per sq. ft. Within limits, deeper bed depths and higher drying temperatures will generally increase output rates. However, berry agglomeration and bleeding should be avoided in order to produce a good explosion puffed product.

Partially dried berries were held at room temperature (c. 73° F.) for 16 hours to equilibrate moisture within and among the berries. Much longer storage is feasible if it is desirable to extend the plant operating season for blueberries or a combination of fruit and vegetable processing. This will be more fully covered under "Storage Tests."

Explosion Puffing

Continuous injection and through-flow of superheated steam during the explosion puffing cycle has necessitated partial drying of the material charged to the gun to a somewhat lower moisture content than previously reported (4). Formerly, the pressure build-up for successful explosion puffing was provided solely by the moisture content of the charged material and was generated by the application of external heat alone. The discharged product was consequently lower in moisture than the initial charge, and the time required to generate the desired pressure often resulted in products with undesirable heat-induced flavors. Injected superheated steam rapidly builds up pressures and minimizes heat exposure. It does result in a minor but unobjectionable increase in moisture.

The explosive puffing gun has been described (6, 12). The cylindrical gun barrel, 10 inches in diameter by 30 inches long, can well accommodate a charge size of 25 lb. of partially dried blueberries. Berries, in this charge size, have been successfully puffed when charged to the gun within a moisture range of 11 percent to 18 percent; hence moisture need not be of paramount concern in plant operations, as long as the partially dried berries fall within these limits. Berries above this moisture range tend to disintegrate on puffing, and below this range tend to be hard and unpuffed.

The distinct advantage in using superheated steam is the substantial reduction in time required per puffing cycle and in the increased charge size per gun load. Formerly, with external heating alone, a 20-lb. charge of berries required 13 minutes from loading to firing; now a 25-lb. charge is ready in 4 minutes. The time reduction in heat exposure, coupled with uniformity in heating medium contact, has resulted in superior products.

Figure 1 shows the explosive puffing gun now used in pilot plant studies. Gun capacity for blueberries is 375 lb. per hour of puffed product at 18 percent moisture, or 338 lb. per hour of material after drying to 9 percent moisture. This capacity makes the gun practical for commercial production. Figure 2 shows the position in the chamber of the perforated tube for steam distribution and the thermocouple for measuring inlet steam temperature.

Preheating the gun and setting desired operating conditions are necessary prior to puffing. The following sequential steps are suggested for initial and subsequent operations (fig. 3):

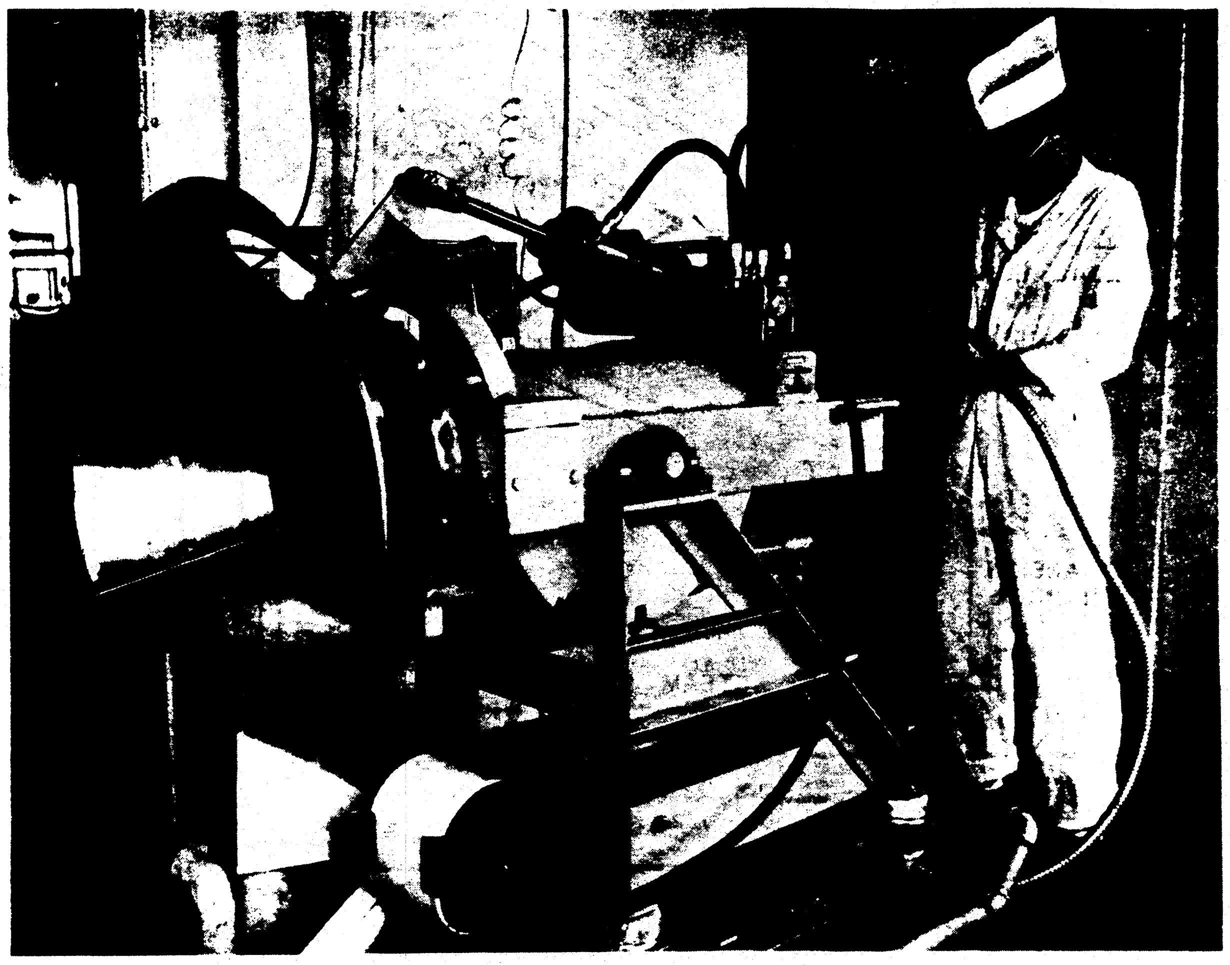

Figure 1. Gun rotating in operating position.

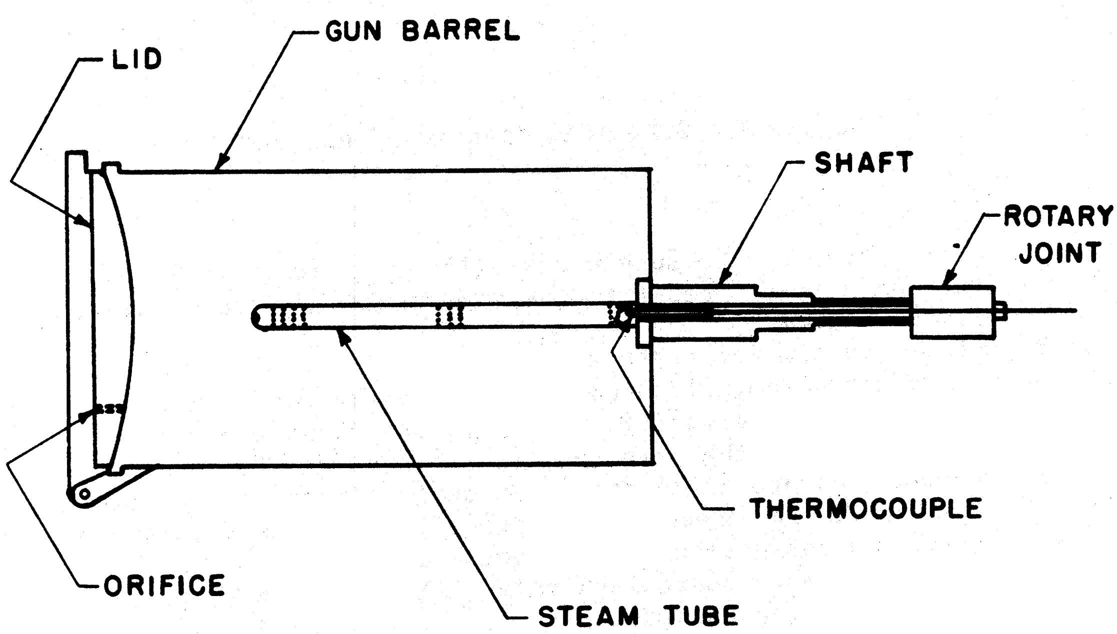

Figure 2. Location of thermocouple and steam distribution tube in gun barrel.

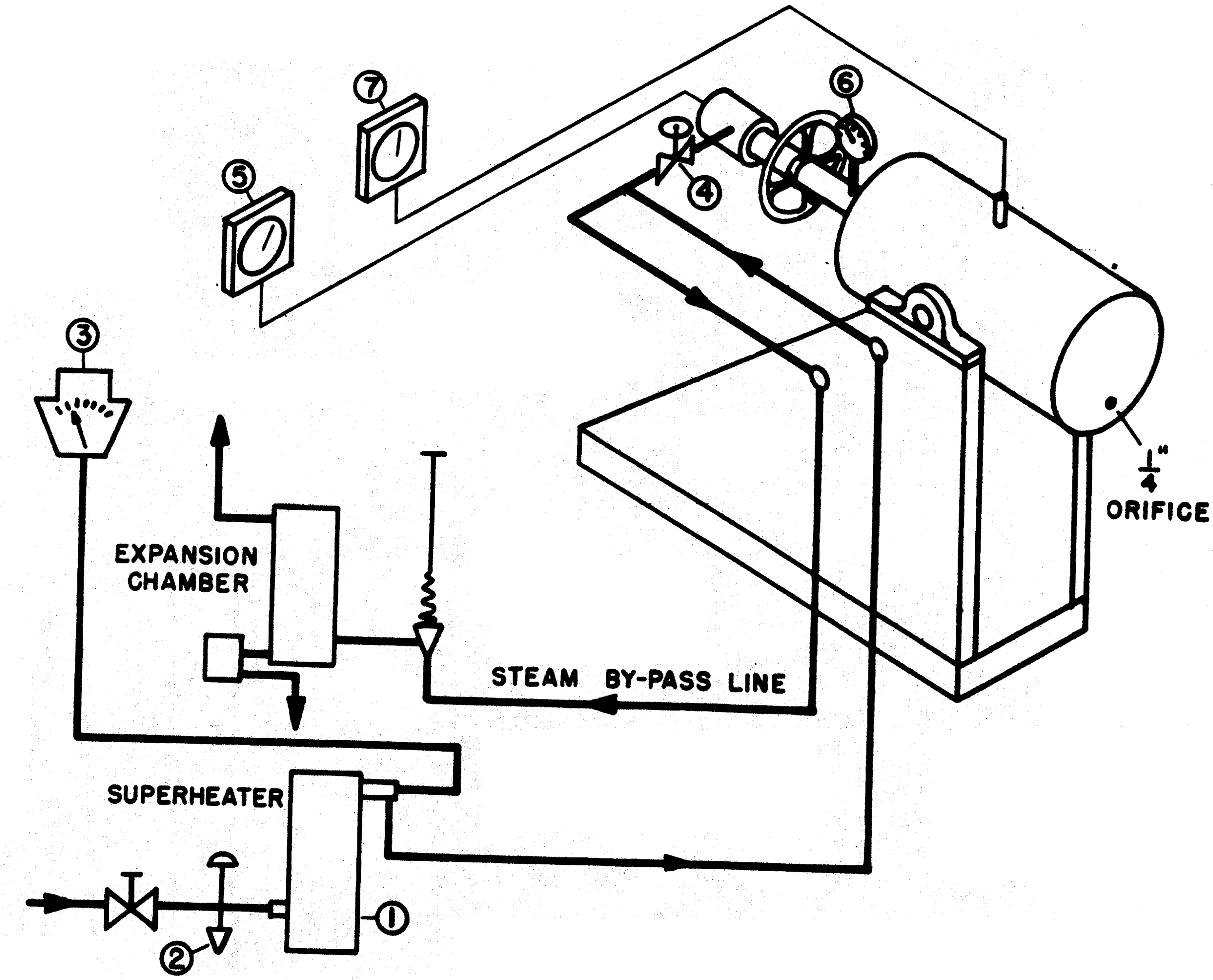

Figure 3. Schematic diagram of gun and operating controls.

1. Admit steam to the superheater (1) by opening valve (2).
2. Turn on electric power to the superheater and set thermostat (3) to give 350° F. steam.
3. Close gun lid and start rotation.
4. Light gas burners located under gun barrel and admit steam to gun through quick-opening valve (4). Steam is now flowing continuously through the gun and exiting at the orifice shown on the gun lid.
5. Adjust gas rate to maintain gun surface temperature between 340° and 350° F. Temperature is shown on recorder (7), which is actuated by a sliding thermocouple on the outside of the gun barrel.
6. Adjust steam pressure with valve (2) to obtain 20 p.s.i. as indicated by gage (6) on gun shaft.

7. Shut off gas to burners, lower gun to firing position, stop rotation, release gun lid and shunt inlet steam to the bypass by closing valve (4).
8. Raise gun to loading position, introduce charge, close lid, lower to operating (horizontal) position, start rotation, relight gas burners and introduce steam (4).
9. Maintain surface temperature between 340° and 350° F. Observe the temperature of superheated steam entering the gun as shown on recorder (5), and adjust thermostat (3) as necessary to achieve 270° to 275° steam temperature (corresponding to 10° to 15° superheat) entering the gun.
10. Steam pressure (6) will begin to rise as soon as valve (4) is opened. Adjustment of valve (2) may be needed to obtain 20 p.s.i. on gage (6) at the completion of the steaming cycle (about 2 minutes).
11. At the end of the steaming cycle, repeat step 7. Product will be discharged and the cycle can be repeated starting at step 8.

Puffed berries are discharged into a sloping tunnel designed to reduce the initial velocity at firing. The tunnel terminates in a tray from which the berries would be conveyed to the final drying stage.

Final Drying

Final drying was conducted in the same dryer as was used for partial drying. Hot air at 150° F. dry bulb and 90° wet bulb was circulated through the bed in a downflow direction at 250 f.p.m. Air direction was not reversed, in order to prevent blowing berries from the trays. Tray loading was 3.0 lb. per sq. ft. (2-inch bed depth), and about 2-1/2 hours was required to dry the berries from an average moisture of 18 percent after puffing to an end moisture of 9 percent. Bulk density at 9 percent moisture was 25.1 lb. per cu. ft. Final drying experiments with reference to optimum tray loadings and bed depths were not conducted.

Explosion puffed berries can readily be dehydrated to 4 percent moisture content or lower; however, at these moistures, the berries are extremely friable. Shipping and handling would result in excessive fines (small chips). This might not be a problem in pie baking, but would be undesirable in muffins or cakes where fines appear as small specks rather than whole berries. On the other hand, too high a moisture produces agglomeration, or stickiness, in the berries. Resolution of this problem was obtained by evaluating berries of different moistures in muffins. Moistures tested were 4.2, 5.8, 8.4, 10.6, and 20.5 percent. (The 20.5 percent sample was considered too sticky for practical purposes.) Both 4.2 percent and 5.8 percent moisture samples were friable and were not satisfactory. The 8.4 percent and 10.6 percent samples were not friable and appeared to be most desirable for incorporation in cake and muffin mixes.

PRODUCT EVALUATION

The true test of a food process is in the edibility of the end products. Product appearance, rapidity of rehydration, palatability, and freedom from bacteriological contamination were the criteria for selecting processing conditions. Berries were evaluated most frequently in baked muffins; they were often tested in pies. Berries undergoing storage tests were similarly evaluated.

The procedure used to test berries in muffins was as follows:

1. Add 28 g. of dehydrated berries to 1 cup boiling water.
2. Cover and simmer 1 minute.
3. Drain in strainer and rinse.
4. Use in lieu of canned berries in recipe with prepared muffin mix.

Each batch of blueberries was sufficient for 12 medium-size muffins.

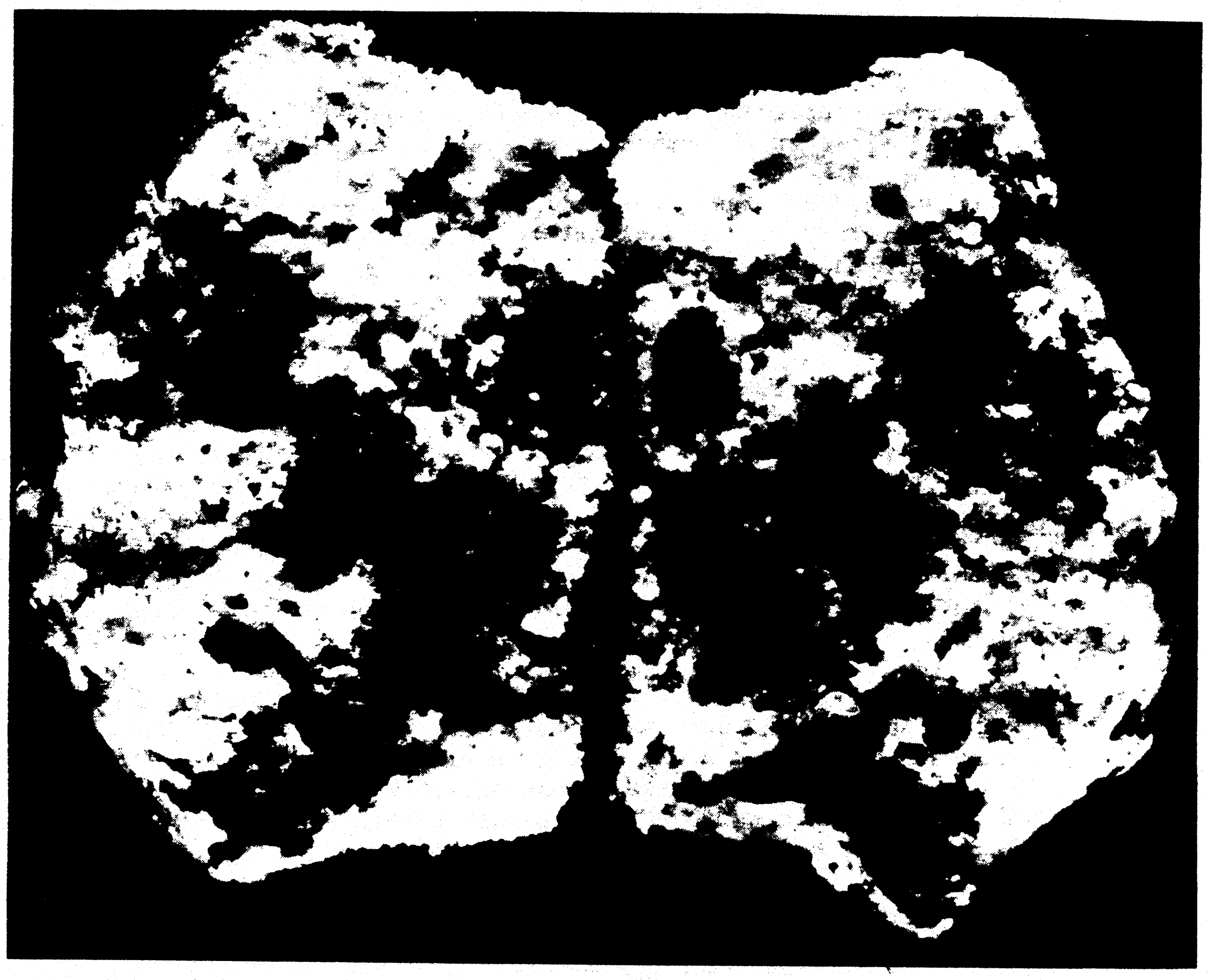

Figure 4. Blueberry muffin. Berries in muffin prepared with explosion puffed fruit are soft and juicy. Conventionally dried berries do not have this attribute.

Muffins prepared by using explosion puffed blueberries (fig. 4) illustrate the soft, juicy character of the berries. Dehydrated, explosion puffed berries must be rehydrated before baking if they are to imbibe sufficient water to yield a juicy product.

A suggested procedure used to prepare a 9-inch pie is given below:

1. Combine 1 cup granulated sugar with 2-1/4 cups water and bring to a boil.
2. Add 113.5 g. (about 4 oz.) of explosion puffed berries and simmer 1 minute.

3. Make a slurry of 5 level tablespoons modified starch,[2/] 1/4 teaspoon salt, and 1 cup of cold water.
4. Add the starch slurry to the cooked blueberries and simmer until mixture is clear and thick (about 1 minute). Add 2 teaspoons lemon juice.
5. While this is cooling prepare pie shell.
6. Pour mixture into pie shell, add top crust, and bake in preheated oven at 425° until crust is brown (20-25 minutes).

STORAGE TESTS

Extending Operating Season

The feasibility of season-to-season bulk storage of partially dried, unpuffed blueberries (as practiced commercially for 20-25 percent moisture apple pieces) was determined by conducting storage tests at 38° and 73° F. Berry samples at 11.1, 15.7, 16.8, and 19.3 percent moisture contents were air-packed in tightly sealed containers and kept for 11 months. Periodic microbiological evaluations were made for total bacteria, flat-sour bacteria, yeasts, and molds.

All samples stored at 38° F. were acceptable microbiologically at the conclusion of the test. The 15.7 percent moisture sample at 73° was discarded after 1 month's storage. Since a 16.8 percent sample kept for 11 months at 73°, it was concluded that extraneous contamination was responsible for the high bacterial count found in the lower moisture sample. After 3 months, the 19.3 percent moisture sample at 73° was discarded owing to positive counts for molds, total bacteria, and coliforms. No increase in micro-organisms took place in the 11.1 percent or the 16.8 percent moisture samples at 73°.

It can be concluded from these tests that proper handling procedures must be used, and that partially dried blueberries in the 11.1 to 16.8 percent moisture range can be safely stored from one season to the next at 73° F. Berries with these moisture contents had a tendency to agglomerate and this could be a problem in bulk storage. Surface coatings such as described under "Bulk Packing 8-10 Percent Moisture Puffed Products" could be used to maintain berries in a free-flowing condition. Storage data on partially dried blueberries have been previously published (7, 8).

Storage of the Puffed Products

Keeping qualities of dehydrated, explosion puffed berries at 4.2 percent and 9.5 percent moistures were determined. Small samples (28 g.), sufficient to provide for 12 medium-size muffins, were individually packed in air or nitrogen and stored at 38°, 73°, and 100° F. Samples used as standards were N_2-packed at 9.5 percent moisture and kept at 0° F. Comparative evaluations were made of berry appearance in prepared muffins and included color and relative rates and degrees of rehydration. Bacteriological tests were also made for total bacteria, coliforms, staphylococci, and molds. Initial analyses showed the samples to be of very good bacteriological quality.

[2/] For example, American Maize Co. Hi-Gloss 400, Corn Products "Snow Flake" No. 4828, National Starch & Chemical Corp. Clearjel 51-6016, or equivalent.

Color analyses were made on the residual water remaining after rehydrating the blueberries. Evaluations were made with a Gardner Color-Difference Meter, and ΔE's were calculated as deviations from the blueberry sample used as the standard. Rehydration of individual samples was checked against the standard sample for apparent differences. The amount of water imbibed by the berries on rehydration returned the berries to about 70 percent of the moisture content of the original, fresh berries. This figure is somewhat higher than reported for dried berries (7, 8). Color and flavor of the stored berries incorporated in the prepared muffins were visually and organoleptically compared with the standard sample.

Results

After 1 month's storage at 100° F., all samples were considered undesirable in color. The berries were brown, resembling raisins rather than blueberries; however, no off-flavors were detected. The lower moisture samples were not as brown, but N_2-packing had no noticeable effect on preservation. Rehydration appeared to be unaffected.

At the end of 6 months' storage, samples at 73° F. had not developed off-flavors and in muffins appeared equally to possess characteristic blueberry color and flavor when compared with the standard sample. All samples rehydrated equally well. Differences in color were detected with the Color-Difference Meter between the higher and lower moisture samples for both air and N_2 packs; however, these differences were not significant ($p=0.05$). The lower moisture samples were close to the standard sample in color. The samples stored at 38° F. appeared virtually unchanged from their original appearance.

It can be concluded that for practical purposes, air-pack storage of 9.5 percent moisture samples at 73° F. for 6 months does not significantly impair color, flavor, or rehydration of the product.

Bulk Packing 8-10 Percent Moisture Puffed Products

Explosive puffed berries at 9.5 percent moisture had a slight tendency to adhere to one another in the pack for muffins (28 g.). Since this might be a problem in larger packs, a test was made to determine the degree of adherence when bulk-packed in No. 10 cans (603 x 700). The effects of two surface coatings were evaluated by coating two lots, one with 1 percent unmodified corn starch (on a blueberry solids basis), and the other with an equal amount of Huber Corporation's Zeolex 7 (prepared sodium silico aluminate). Coated berries were free flowing and rehydrated as rapidly and to the same degree as uncoated berries. Coated and uncoated lots were air-packed and stored at 73° F. for 1-1/2 months. Cans were tapped at frequent intervals to simulate jarring in shipping and handling.

At the end of the test, can contents were examined. Berries were poured from the cans to observe their degree of adherence. The uncoated berries remained fairly free flowing, with no more adherence than when packed--only slight tapping of the can was required to empty can contents. Both coated samples were somewhat more free flowing. All samples rehydrated equally well.

It can be concluded that at 9.5 percent moisture, berries need not be coated to prevent adherence when bulk-packed.

COSTS

Detailed cost estimates have not been made for explosion puffed blueberries. However, it has been shown that explosion puffing of carrots and potatoes increased cost of manufacture only 10 percent to 20 percent above that for their unpuffed counterparts. It is probable that the increase in the cost of blueberries would be moderate for two reasons:

(1) The berries, when predried to the proper moisture for puffing can be kept for long periods and, where necessary, shipped from distant areas. This enables combining operations with those for other commodities such as apples, carrots, potatoes, and beets, thus permitting year-round use of puffing equipment.

(2) Unlike puffed apples and carrots, which require drying to final maximum moistures of 2.5 percent and 4 percent, respectively, blueberries need only be dried to between 8 percent and 10 percent.

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